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Sponsoring Organisations: Department of Industry, London, and
University of Lancaster, England.

Second Progress Report Number 2-14/P6 for the period 1 September,
1979 to 31 December, 1979.

ORIGINAL CONTAINS

COLOR ILLUSTRATIONS

Original photography may be purchased from
EROS Data Center

2-14/P6-1

Objectives of Investigation

Sioux Falls, SD 57198

The overall aim of this research is to investigate the
feasibility of the use of data drawn from the visible and
near-IR (0.5 to 1.1 μ m) and from the thermal IR (10.5 to
12.5 μ m) bands of NASA's Heat Capacity Mapping Mission
(Explorer-A satellite), as applied to the sea surfaces
centring on the North Sea, to study marine pollutants,
particularly oil.

2-14/P6-2

Principal Accomplishments

The video processing system (2-13/P5-3) was modified by
the introduction of a microscope, to facilitate the examination
of small areas of the images, between the transparency stage
and the CTV camera.

Some 890 NASA transparencies and 300 Lannion QL prints
have been put on computer file in such a way that images

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taken on a given date can be recovered rapidly. This facility has been used in a search for imagery covering the periods of persistence of the 69 longest oil spills sighted in offshore regions of the U.K. in the calendar years 1978 and 1979. Of these spills, 18 were in areas which corresponded to imagery acquired for the dates ($\pm 1d$) in question.

Tests with the indoor simulator (2-13/P5-3) were completed under a range of values of relative humidity, and the results were analysed with a view to determining the influence of ambient conditions on the surface temperature of an oil slick relative to the surface temperature of similarly placed (but uncontaminated) water.

The effect of wind on the heat balance regimes in oil slicks at sea has been investigated using computer routines, since wind is another environmental factor which bears on the problem of the relative temperature of exposed oil, and water, surfaces.

2-14/P6-3

Satellite Data

A total of 1000 positive and negative HCMM transparencies covering parts of the marine areas around the U.K. have been received since 30th April, 1979. These transparencies have been coded, catalogued and filed manually. Since 8th June, 1979,

400 Lannion QL positive and/or negative HCMM prints have also been received and these prints have, likewise, been coded, catalogued and filed manually.

2-14/P6-4

Sea Truth

Sea surface temperatures and other sea surface data for four test locations (Fig. 1), each corresponding to a specific date and time, were ordered through METO 12c and were received after three weeks delay.

The southern Shetlands area (Fig. 1a) was examined for traces of pollution around the coast where there is a concentration of shipping and oil terminal activity. The spindle-shaped red feature was, however, identified as cloud. In Area (a) red is cool and blue is warm.

Limiting the sea truth to the time of satellite overpass would have virtually eliminated the input of surface data into the investigation. A compromise was reached in which sea truth data were extracted over an arbitrary six-hour time interval centring on the time of the acquisition of HCMM imagery by satellite. Even then, Area (a) contained no surface temperature data over the six-hour time interval centring on 12Z (midday) of 1978 May 10.

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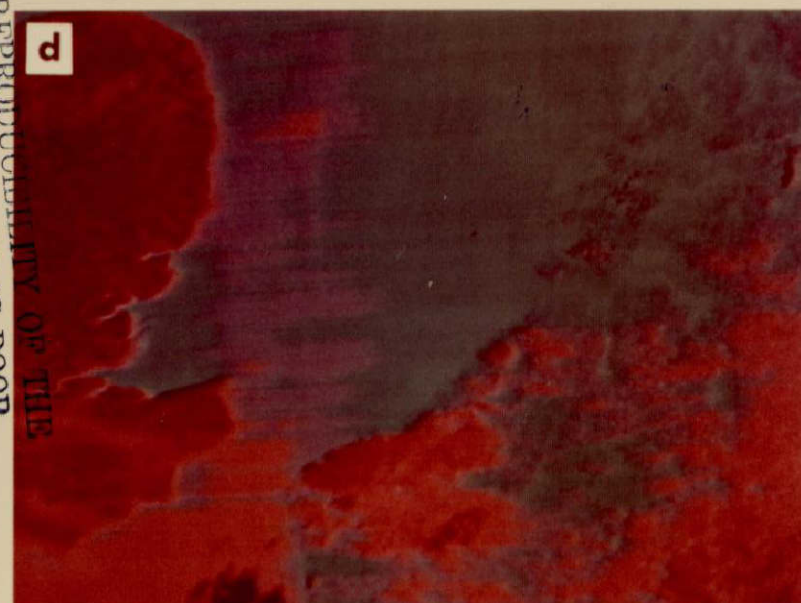
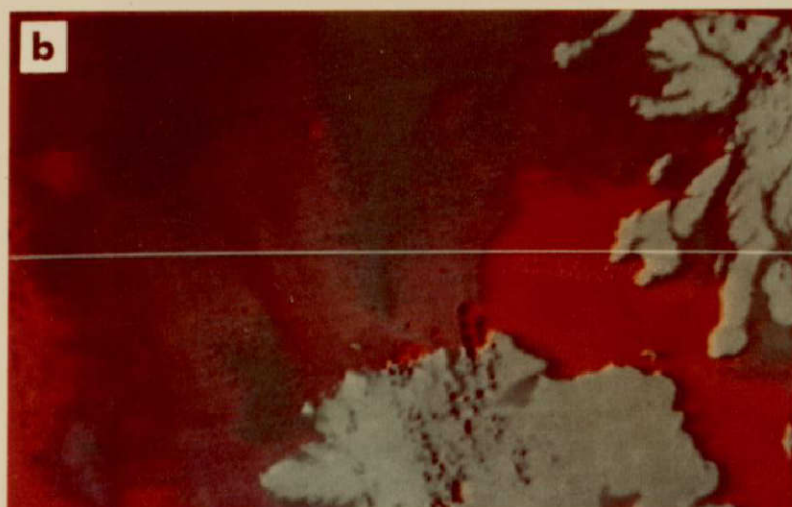
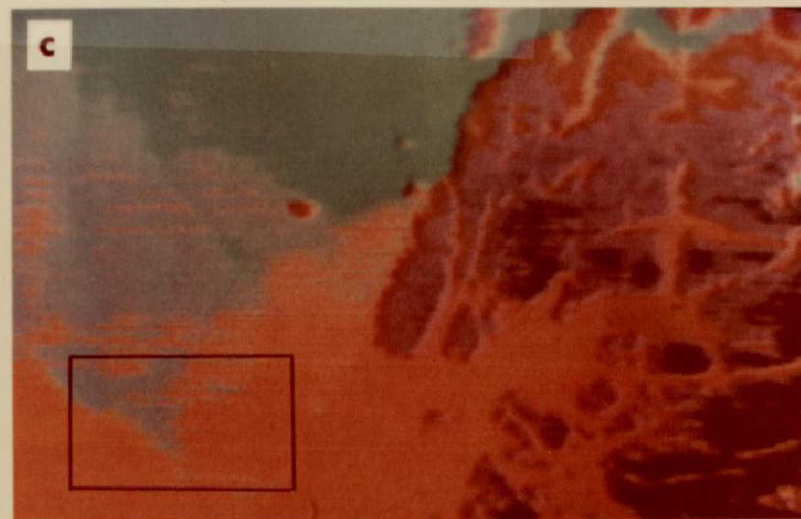
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Fig. 1

In Fig. 1b, the temperature again increases through red, magenta, blue and cyan. A densitometric profile along the horizontal line shows a good correlation with the Ice Chart (sea truth) temperatures. However, the Ice Chart data fail to show the prominent and persistent Islay Front feature shown here as a purple/red boundary which extends northwards from the N. Ireland coast; and the degree of correlation between the reported sea truth temperatures and the thermal contours of the satellite imagery is poor.

Area (b) contained only one SHIP temperature measurement centring on 12Z of 1978 June 1.

In Figs. 1c and d the colour coding is the reverse of that specified for Figs. 1a and b. The region demarcated in Fig. 1c by a black rectangular boundary (a marine area off Stavanger, Norway) is shown (Fig. 2) in the uncorrected, digitised display on the PET screen. (The same display is seen recalled from disc-file in Fig. 3). In this demonstration of the technique, the effects of raster lines are evident in both images. Some discrepancies are evident in the two images, which were prepared on different occasions. Particular care was taken to minimise camera shading and uneven illumination while preparing the digitised image, but the effects of image raster lines are clearly seen in the absence of correction. The same BASIC

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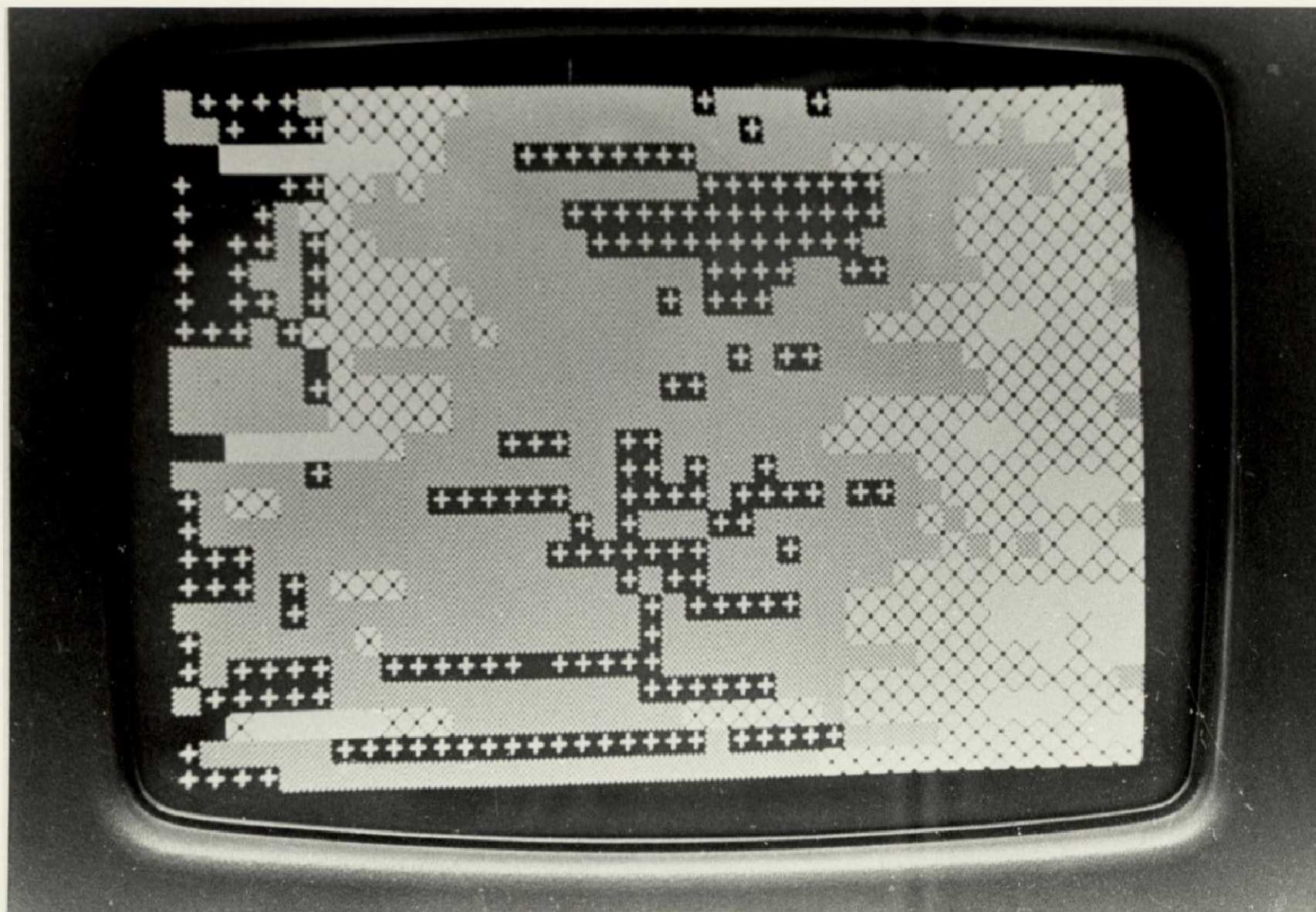


Fig. 2

program was used to generate both this display and also the corrected data for the printout of part of Anglesey, discussed below.

Area (c) contained only two SHIP temperatures centring on 12Z of 1978 May 28.

The image of Fig. 1d was taken during the period of the "Eleni V" spill on 1978 May 30; but the picture is dominated by the presence of raster lines present in the original hard copy. This area (Dover Strait and River Thames) contained eight British Light Vessel (BLV) temperature measurements and three SHIP temperature measurements, all centring on 00Z (midnight) of 1978 May 30.

Most of our total area of investigation is without BLV data, which concentrate in the Dover Strait - Thames estuary area and provide temperatures to the nearest whole degree. This may be compared with the one-tenth of one degree temperature data reported on the SHIP coding (but the significance, and usefulness, of this degree of precision is questionable). None of the four test areas contained any BATHY temperatures.

The Ice Chart five day mean temperatures are deduced from the observations made from a stated number of ships within a given square of side one geocentric degree: the sides of the

square run parallel, and perpendicular, to parallels of latitude. Correlations of all the sea surface temperature raw data with the Sea Ice Chart five day mean temperatures is mostly good even though the raw data in question refer to the central six hours of the five day period. In the case of each of the test areas (a) (b) and (c) it is impossible to draw reliable isotherms through the six-hour temperature data. An attempt to construct meaningful isotherms through the relatively densely clustering sea truth points in Area (d), may, however, be made.

Whereas the Sea Ice Charts are based on BLV and SHIP observations of temperature, and Coastal Ice Charts include additional data such as that received from Icelandic vessels. We conclude that the best sea truth base on which to put the HCMM imagery is that provided by the Coastal Ice Charts, even though they provide only five day means. Data other than temperatures (for example, wind and wave data, visibility, and so on) would still have to originate in BLV reports (not available in most areas) and in sparsely distributed SHIP reports.

U.K. Coastguard and rig reports of oil spills in the period of interest (1978 and 1979) have been made available to us through the Department of Trade, London. No major oil slicks have been reported by the Department of Trade in the

same period and in the area of investigation. One slick, reported to us through the Marine Science Laboratories, Anglesey, is discussed in 2-14/P6-6. Attempts to gain technical information on major slicks elsewhere in the world have so far proved negative.

2-14/P6-5

Methodology used in Performing the Investigation

HCMM transparencies and QL prints are scanned visually, sorted and catalogued manually: then the images are passed to the Co-I. for coding and insertion on the PET data file. All images which correspond to dates of reported oil spills are located in the data file and extracted for quality examination in the particular, small area of interest, using the colour video slicing, videodensitometric, and picture digitisation, equipment depicted in Fig. 3. The video signal from the Link Electronics black and white CCTV (A) is fed via the video slicer and PAL colour encoder (B) to the colour video monitor (C). The camera video signal is also fed to the raster analyser for line selection (D) and the video strobe unit (E). Storage oscilloscope display (F) of a single line can be monitored while waveform digitisation with the A/D converter (G) allows processing of the selected portion of an image with the PET microcomputer (H). The Computhink floppy disc system is seen to the right of the PET, behind which (not



Fig.3

visible) is the X-Y plotter for producing single-line trace hard copy. A Creed 7 teleprinter (not shown) is employed for producing the equivalent hard copy printout of the PET screen image display.

The aim of the indoor simulation experiment was to determine, for given environmental conditions, the surface temperature of a given volume, v , of North Sea oil overlying a given volume, V of water and to compare the observed temperature of the oil with that of a surface of uncontaminated water of volume $V + v$ (where $V \gg v$). By conducting such an experiment it is possible to assess the likely response of the HCMM heat sensors to an oil slick at sea. Our first experiment in the laboratory made use of a pyroelectric radio-meter and phase-sensitive detector to compare the heat flux deriving, respectively, from the surface of a volume, V , of water, and a surface film of crude oil covering a second volume V of water. The surface oil remained at a sensibly higher temperature than that of the comparison water surface.

In an attempt to discover the reasons for this difference it was decided to examine the following hypotheses:-

H1 - The water-with-oil (System A) and water (System B)

systems were not in identical thermal situations in thermal equilibrium;

H2 - System A alone was exhibiting a radiation balance regime similar to a "greenhouse effect";

H3 - System B was being cooled, by evaporation, faster than System A;

H4 - The surface temperature of System A depended on the thickness of the oil layer.

Accordingly, the equipment was improved (Fig. 4) in order to (a) minimise differences in the initial thermal conditions of each of the systems; and (b) introduce direct temperature read-out at a few selected points in, and above, each system. Then the liquid systems were carefully re-established as follows. System A was prepared by measuring 2.8 litres of tap water at room temperature and introducing it to a polythene bowl. This water was covered (in the first instance) by 400 cm^3 of oil, at room temperature, to give an overall depth of the fluids of 6 cm. System B was prepared by measuring 3.2 litres of tap water at room temperature and introducing it to a polythene bowl which was virtually identical to the first. The oil of System A was crude terminal oil from the Ekofisk Field. It was noted that the only difference between the terminal oil and the rig oil was that the former had lost its high volatile component. In the case of an oil spill in the sea this component would vaporise and dissipate almost

immediately; so the present experiments would be relevant to the spill situation.

Temperature Sensing Points

- 1,5,6. air
- 2,4; surface of water
- 3. bulk of water
- 7,9; surface of oil layer
- 8. water beneath oil

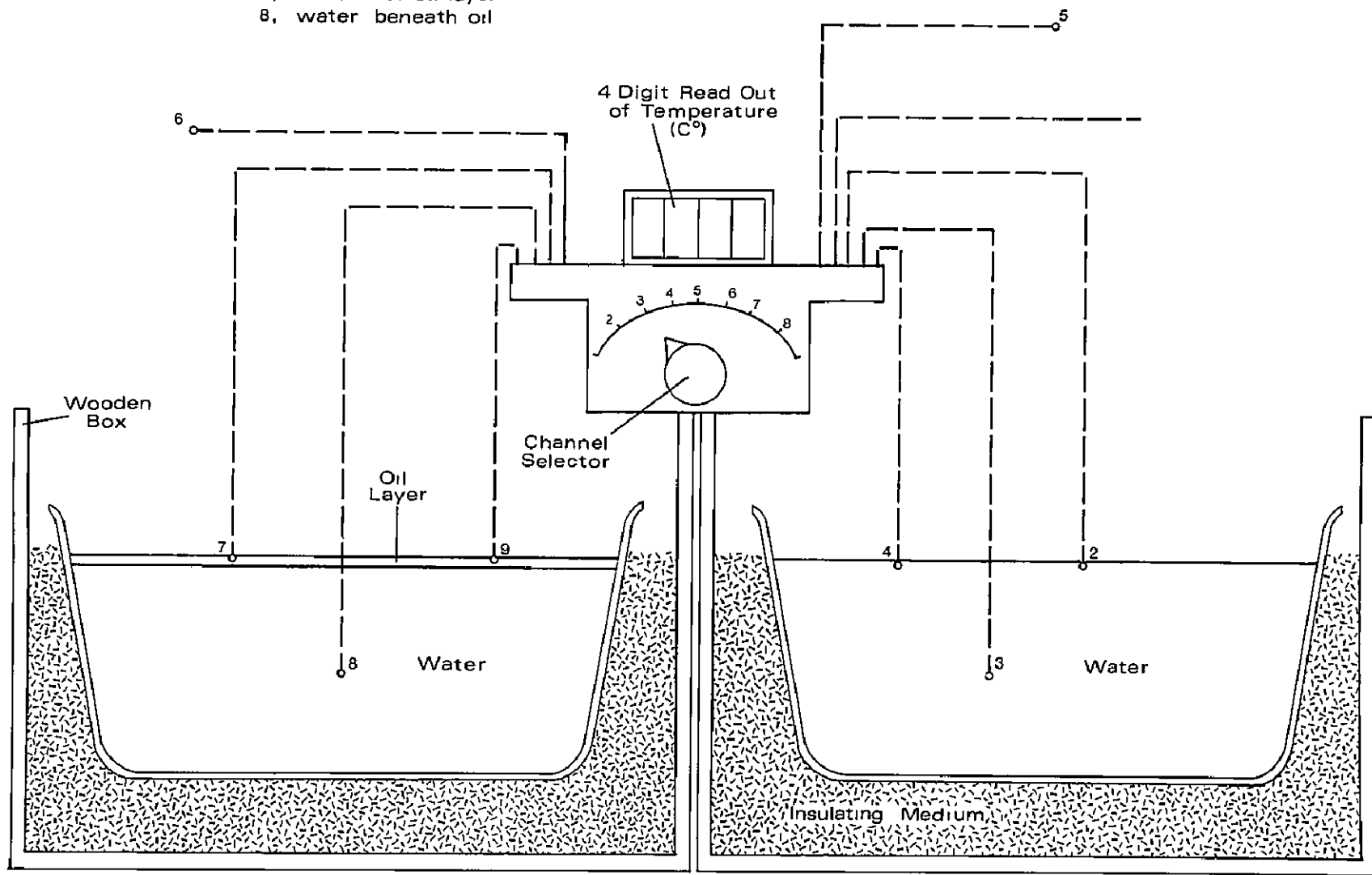


Fig. 4

Each polythene bowl was embedded in a medium of PVC packing chips contained in a thick-walled wooden box and the boxes (Fig. 4) were placed in lateral contact. The bottoms and sides of the bowls were thus effectively insulated from the surroundings; and the walls of the boxes rose well above the liquid surfaces so as to minimise draughts and maintain similar ambient conditions above each system. A wooden gantry was mounted over the top of the boxes in a position of symmetry with respect to the two polythene bowls. Miniaturised Pt-resistance temperature probes were supported by this gantry and placed in strategic positions (the points 1 ... 9, specified in Fig. 4). The temperatures at these stations were displayed, in turn, as four digits on a Farnell Instruments DRT 2 Unit, the stations being selected by means of a Cropico, Ltd., low contact resistance switch.

In this and subsequent experiments, the equipment was left to attain an equilibrium state before measurements were commenced. It was found that an interval of one day was normally sufficient for this purpose. In order to test H4, the thickness of the oil layer was changed several times over the range ~ 1 mm to 1.9 cm.

Table 1 shows results of a representative run at sensibly constant, and low, relative humidity ($< 10\%$) but with varying oil layer thickness.

Care was taken to ensure that the platinum resistance thermometer elements could be held rigidly in their appropriate positions by enclosing the leads in soft aluminium tubing, which was bent to the required shape in situ. Evaporated water in the water-only vessel was topped up at the start of an experimental run. Equilibrium temperatures of each probe were measured sequentially, using the rotary switch which was fixed on the rigid wooden gantry along with the digital electronic thermometer unit. During these experiments, the probes were left in position, only minor adjustments being made as required.

It is evident from Table 1 that there is little change in the difference between the oil layer surface temperature and that of the water surface. The actual temperature difference is about one Centigrade degree in all cases, the oil surface being consistently the warmer.

The relative contributions of H2 and H3 were assessed by changing the ambient humidity using a temperature controlled water bath in the closed laboratory. A whirling hygrometer was used to measure the relative humidity of the air in the laboratory for a range of equilibrium conditions. Relative humidities covering the range of from $< 10\%$ to 65% were generated in this manner.

RH < 10%

Thickness of oil layer	0.02 cm	Left overnight 0.02 cm	0.1 cm	0.75 cm	1.13 cm	1.50 cm	1.88 cm
Oil Surface (7, 9) Mean T °C	20.40	21.15	21.85	22.15	19.75	21.00	22.05
Water Surface (2, 4) Mean T °C	19.55	20.20	20.70	20.80	18.1	19.20	20.35
Bulk Water (8) Under Oil Mean T °C	20.35	21.05	21.45	21.95	19.80	20.65	21.25
Bulk Water, Mean T °C (3)	19.60	20.15	20.65	20.70	18.15	19.15	20.00
Air (1, 5, 6) Mean T °C	21.50	22.35	22.90	23.35	20.35	22.00	23.50
Difference in Surface T °C Oil-Water	0.85	0.95	1.15	1.25	1.65	1.80	1.60
Difference in Bulk Water and Water Surface, T °C	0.80	0.75	0.65	1.15	1.70	1.45	0.90
T °C Difference (Bulk water under oil - Bulk Water)	0.75	0.90	0.80	1.25	1.65	1.50	1.25

TABLE 1

Table 2 relates the results found when the relative humidity was varied at constant oil layer thickness. There is a noticeable trend towards smaller surface temperature differences as RH increases; and there is a tendency for the temperature difference to level off at about 50% RH.

It will be noted that the difference between the surface and the bulk temperatures of the water-only bath also decreases with increasing RH, as does the temperature difference between the bulk water-under-oil and bulk water (only) in their respective baths.

In these experiments, the observational evidence suggests that the main contribution responsible for the surface temperature difference is the permitted evaporation of water at the water-only bath surface, an effect which would be increasingly important at low RH.

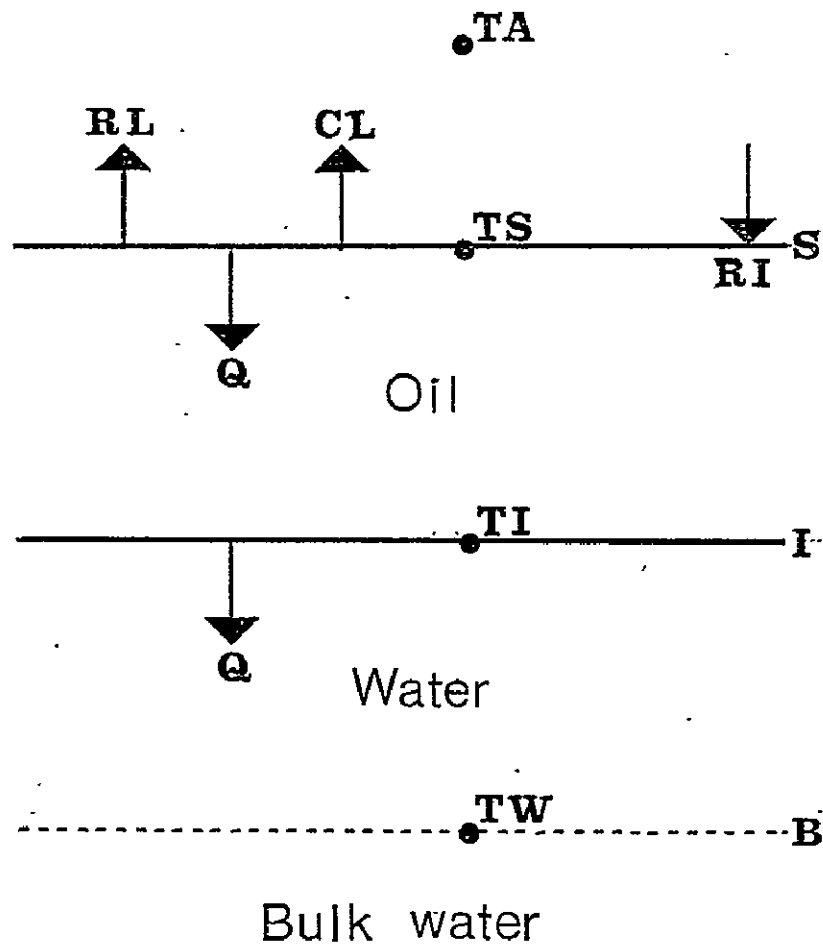
Increasing the oil-layer thickness has relatively little effect in cases of thickness in excess of 1-2 mm. However, it is expected that, under calm conditions in the open sea, the surface temperature of isolated aggregates of heavy crude oil would be sensitive to thermal radiation balance.

Attempts to model simple oil-slicks, using computer simulation (Fig. 5) indicate that an additional important factor, not yet explored in our experiments, is wind velocity.

Oil layer thickness 1.88 cm	RH				
	< 10%	20%	50%	65%	< 10%*
Oil Surface (7, 9) Mean T °C	24.10	23.95	25.15	25.95	27.90
Water Surface (2, 4) Mean T °C	22.20	22.50	24.00	24.75	24.95
Bulk Water (8) Under Oil Mean T °C	24.30	23.50	24.40	25.05	25.30
Bulk Water, Mean T °C (3)	22.20	22.30	23.65	24.4	23.90
Air (1, 5, 6) Mean T °C	23.90	25.30	26.20	26.80	33.30
Difference in Surface T °C Oil-Water	1.90	1.45	1.15	1.20	2.95
Difference in Bulk Water and Water Surface, T °C	2.10	1.00	0.40	0.20	0.35
T °C Difference (Bulk Water Under Oil - Bulk Water)	2.10	1.20	0.75	0.55	1.4

* Warm room: repeat after 5½ hours.

TABLE 2



Key

- RI = Radiative Input
- RL = Radiative Loss
- CL = Convective Loss
- S = Air/Oil Interface
- I = Oil/Water Interface
- B = Boundary between "surface water" and "bulk water"
- Q = Conductive heat loss from surface S
- TA = Air Temperature
- TS = Oil Surface Temperature
- TI = Temperature at Interface I
- TW = Bulk Water Temperature.

Fig 5

The model represented in Fig. 5 is of an infinite, flat sh
Forced convective heat transfer between the ambient air an
the relatively stationary oil surface layers is most effect
under conditions of non-laminar airflow. This occurs at w
speeds in excess of ~ 4 m/s. At these speeds, the tempera
of the oil surface would be expected to follow that of the
air more closely than would the temperature of the water,
has the greater thermal conductivity.

This is exemplified in the following two dummy runs
involving steady states in which the wind speed is held co
stant but the air flow is first laminar and then turbulent

Air Parameters

Wind vel 3 m/s

RI fixed at 200 W/m^2

Reynolds No., $Re \text{ (air)} = 1.2 \times 10^6$

Prandtl No., $Pr \text{ (air)} = 0.71$

Nusselt No., $Nu = 0.037 \times Re^{4/5} \times Pr^{1/3}$ (Turbulent f

$Nu = 0.332 \times Re^{1/2} \times Pr^{1/2}$ (Laminar flo

Thermal Conductivity of air $KA = 2.57 \times 10^{-2} \text{ W/m K}$

Convective loss = $Nu \times KA \times (TS - TA) \text{ W/m}^2$

Radiative Parameters of Oil

Absorptivity, $AB = 0.5$

Rate of energy input at surface $OR = AR \times RT = 100 \text{ W/}$

Emissivity, $EM = 0.5$

Radiative loss $RL = EM \times SB \times TS^4 \text{ W/m}^2$

where $SB = \text{Stefan-Boltzmann Const} = 5.67 \times 10^{-8} \text{ W/m}^2 \text{ K}^4$

Nett input at surface $Q = QR - RL - CL \text{ W/m}^2$

Conductivity Parameters

(a) Oil

Thermal conductivity $KO = 0.138 \text{ W/m K}$

$Q = KO \times (TS - TL) / XO \text{ W/m}^2$

where $XO = \text{oil layer thickness (m)}$

(b) Water

$KW = 0.6$

$Q = 0.6 \times (TI - TW) / XW \text{ W/m}^2$

where XW is the "surface water layer" thickness

Overall transfer coefficient $U (S \rightarrow B) = Q / (TS - TW)$

Thermal resistance $TR = 1/U = XO/KO + XW/KW$

Surface temperature $TS = Q/U + TW \text{ K}$

Interfacial temperature $TI = (TS - TW) / B + TW \text{ K}$

where $B = 1 + \{XO \times KW / (XW \times KO)\}$

Let $XO = 0.1 \text{ m}$ and $XW = 1 \text{ m}$; then $B = 1.4348$

Results

<u>Laminar Flow, 3 m/s</u>	<u>Turbulent Flow, 3 m/s</u>
Putting $TW = 283$ and	Putting $TW = 283$ and
$TA = 288$, then	$TA = 288$, then
$TS = 279.44$ and	$TS = 286.50$ and
$TI = 280.52$	$TI = 285.45$

It is seen that the oil surface temperature follows that of the ambient air more closely in the case of turbulent flow than in the case of laminar flow. It is therefore important to know the prevailing weather conditions in the case of a real event.

The outdoor simulator (Fig. 6) is equipped with a moveable gantry, across which the support plate for sensors and cameras can be moved by means of a rope and pulley system. The 1 m diameter tanks of PVC can be filled and emptied, as required, with a water-suction pump. As in the case of the indoor simulator, one tank contains water, the other water covered by a film of oil. Orientation of the plane of the gantry is at 90° to the daytime satellite orbit and the simulator is positioned in such a way as to have unobstructed access to sunlight.

The outdoor simulator was used to establish that, in sunny conditions, the oil surface presented the higher temperature. In this preliminary experiment with the outdoor simulator, surface and bulk temperatures were monitored directly using the same PRT sensors and digital electronic Unit shown in Fig. 4. (The configuration of the aluminium tubing used to support the PRT leads was changed appropriately). However, Fig. 6 shows the gantry of the outdoor simulator



Fig. 6

supporting two cameras and an IR sensor. The camera shutters are actuated remotely, by use of a pneumatic line, and the PSD for the IR sensor is housed inside a nearby building.

2-14/P6-6

Accomplishments Based on Data Use

At 3 p.m. on 10th October, 1978 the forecastle lookout on the Shell Tanker "Litiopa" observed a spray of oil discharging from a hose at Amlwch Marine Terminal, Anglesey. The discharge was arrested but the slick, which was then moving eastwards under the influence of the flood tide, extended some 1000 m from east to west and some 200 m from north to south.

Estimates of the amount of oil spilled varied from 20 tons to 200 tons. The position and configuration of the slick changed over the following twelve days until there were no visible traces of it remaining in the area.

An attempt was made to correlate the image patterns of the appropriate marine areas in HCMM and NOAA5 scenes with the report of the slick. The linear resolution (about 1 km) and signal/noise ratios of the NOAA5 image - a positive print representing the scene on 1978, October 17 - were deemed insufficient for a detailed, intensive study of the area.

In order to improve discrimination between adjacent image areas our only suitable HCMM transparency - which also showed a 1978, October 17 scene - was, first, suitably masked.

Pixels may be identified readily in the enlarged print of Anglesey (Fig. 7) taken from that transparency. The masked portion of the transparency (DIR) was mounted on the microscope stage (Fig. 8b) and that part of the image which lay within the white rectangle (arrowed, in Fig. 7) was examined using the CCTV camera in position above the x10 eyepiece. With an objective magnifying x4, the enlargement was more than sufficient to resolve the individual pixels.

The false colour rendering of the smaller area in which the slick was reported is reproduced in Fig. 8a. This was digitised and corrected for shading and illumination errors (Fig. 9a). In Fig. 8a, the letter A refers to a cloud over the eastern extremity of Anglesey, B to another cloud which partially covers Puffin Island, C to the suspected slick area (outlined), and D to a patch like C but further from the centre of the area in which the slick was reported and with a temperature which is marginally closer than that of C to the temperature of the surrounding sea surface. In fact, temperature increases through the false colour sequence white, pink, yellow, and green.

Clearly, a region cooler than its surrounding sea area is observed about 2 km NW of Puffin Island (Fig. 9a and b). The observed effect is attributable to a temperature difference estimated to be about 1 K. The spatial extent of the cool patch C, in Fig. 8a, is estimated, from Fig. 9a, to be approximately

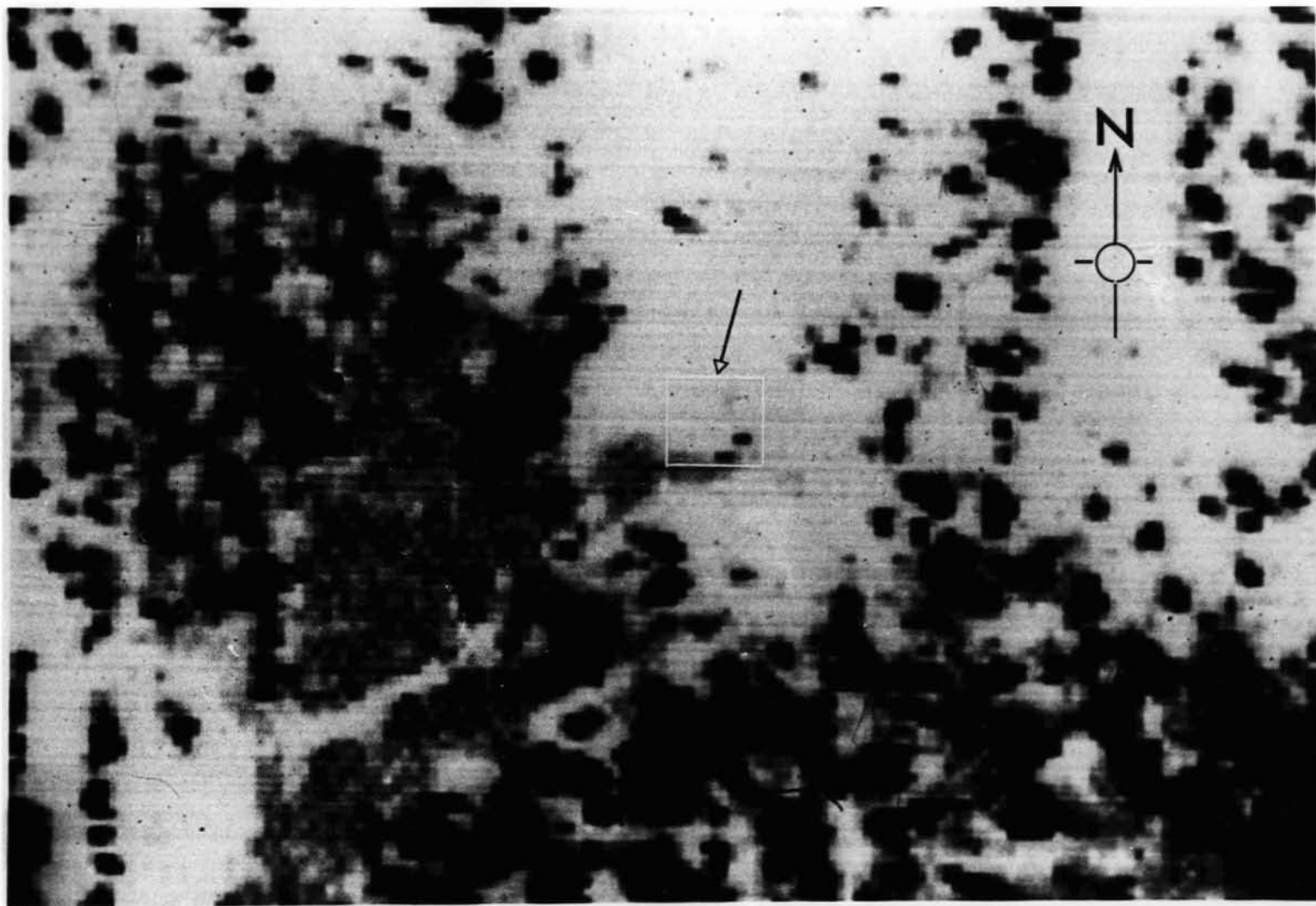
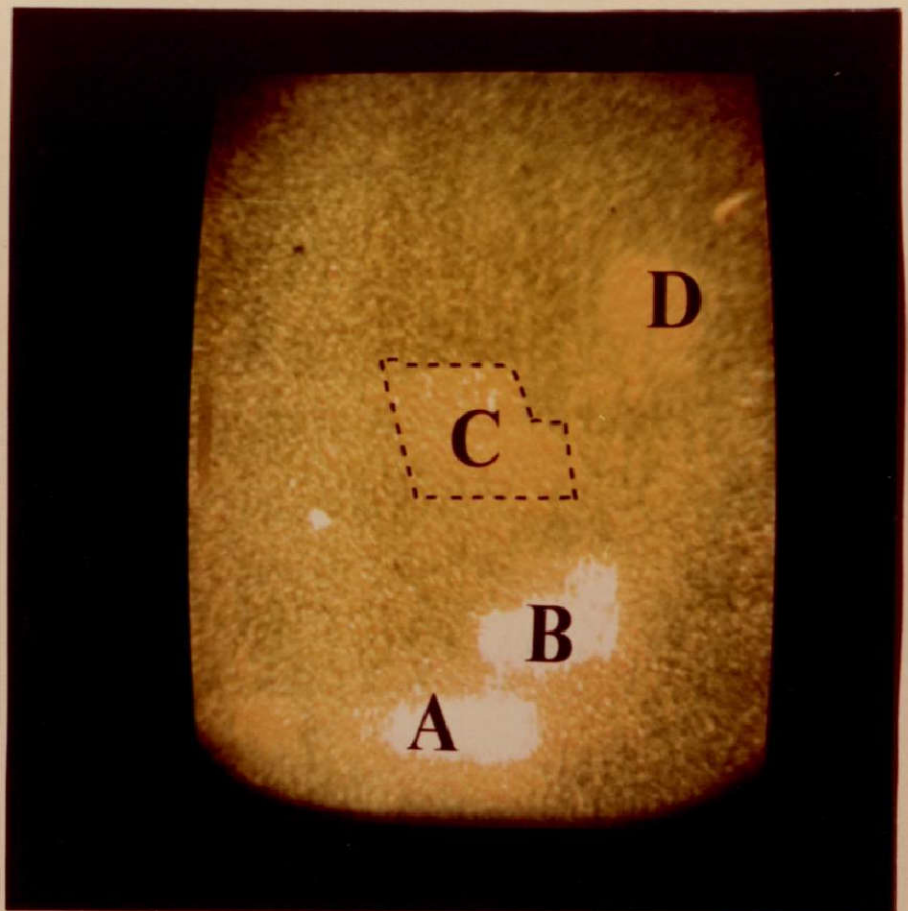


Fig. 7



a



b

Fig. 8

-21-

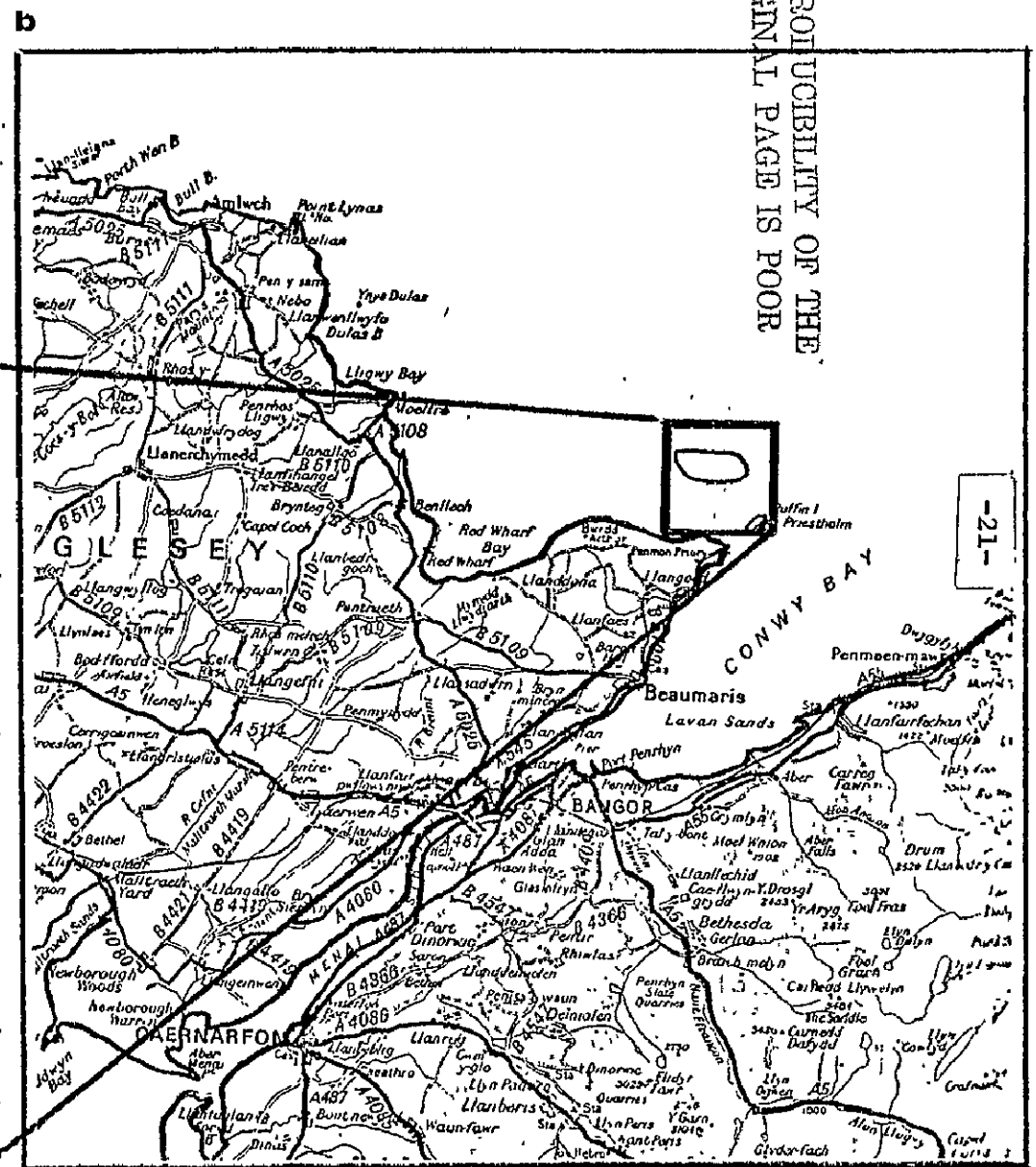
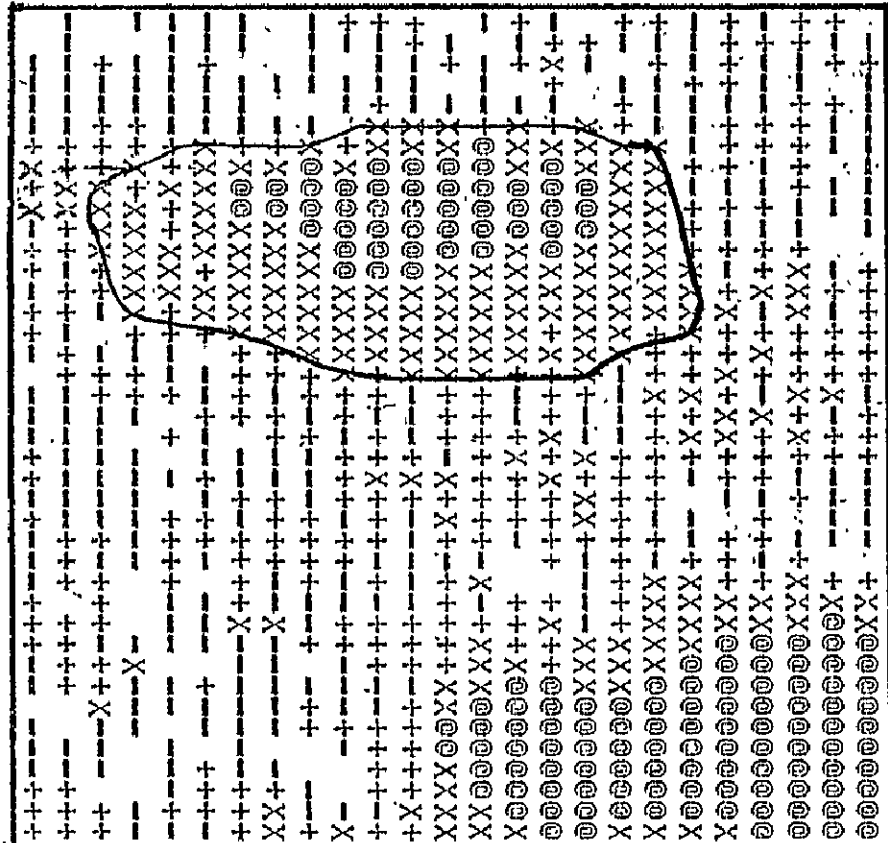


Fig. 9

4 km in the E - W direction and 1 km from N to S. The presence of some cloud (Fig. 7) - and some reported fog - in the area does not, however, lead one to an unambiguous interpretation in this case. Indeed, even the extent of the cloud which partially covers Puffin Island is difficult to assess because of the inherent limits of spatial resolution provided by the imagery.

2-14/P6-7

Significant Results

The image processing techniques developed at Lancaster are well adapted to the exploration and isolation of local areas which exhibit small temperature differences between themselves and their surroundings. In the worst case of imagery of small areal extent of sea surface having no coastal boundary in the area there is, as yet, no method of distinguishing, unambiguously, an oil spill from fog, cloud, the effect produced by shallow sediments, or the effects of naturally occurring thermal fronts. It is probable that such a case might be solved only with the additional input of sea truth relating to the area in question. Ideally, much more concentrated sources of sea truth (surface, and above surface, data) are required even in the case of events recorded on imagery covering wider, relatively cloud-free areas.

NASA-CR-162584

In addition, the application of these image processing techniques would benefit greatly from improved spatial resolution in the original imagery. In many cases, the existence of the major contribution to image imperfections - namely, scan (raster) lines in the original images - far outweighs those imperfections introduced by electronic, shading, and illumination, effects in the equipment.

In the case of uniform slicks of liquid North Sea oil in "still" air, our laboratory simulation experiments have shown that, for oil layer thicknesses in excess of 1 or 2 mm, there is, under equilibrium conditions, little dependence of oil surface temperature on the thickness of the oil layer. The surface temperature of the oil is consistently higher than that of the water surface, the difference being about 1 K at low values of relative humidity but tending to decrease as the relative humidity increases.

Computer simulation has shown that the temperature of an oil layer surface closely follows the temperature of the ambient air under conditions of turbulent air flow. In the field the air flow might be expected to become turbulent at wind speeds in excess of about 4 m/s.

2-14/P6-8

Publications

No in-house or other reports have been published since the date of the First Progress Report (No. 2-13/P5) of 31st August, 1979. The Co-I. has delivered one lecture at a meeting at the Appleton Laboratory of the S.R.C., arranged by the British Interplanetary Society and entitled "Small Systems Processing of Planetary Imagery". The abstract of the lecture is reproduced here.

In the processing of planetary imagery, considerable benefit may be derived from the small systems approach, particularly during the selection of features of interest for more intensive study. This paper outlines the basis for a system involving the use of low cost electronic modules and a microcomputer in conjunction with a good quality closed-circuit black and white camera and a colour video monitor. The system described may be readily adapted to suit individual requirements and was evolved during a project, supported by the Department of Industry, which concerns analysis of Earth orbiting satellite imagery.

2-14/P6-9

Problems

Dr. Duncan Telfer, the Co-Investigator, submitted his resignation to Lancaster University on 29th October, 1979, in favour of a somewhat longer term of appointment to commence

at the University of Manchester's Institute of Science and Technology on 1st January, 1980. The D.O.I. has approved the P.I.'s proposal to extend the Agreement made between the D.O.I. and the University of Lancaster to 31st December, 1980

Addendum (2-14/P6-9)

Dr. Duncan Telfer has decided to turn down the post offered at U.M.I.S.T. in order to continue his Research Associateship with this project.

2-14/P6-10 Data Quality and Delivery

Raster lines have proved troublesome on several occasions. The raster lines, which are present in the original transparencies can be an important limiting factor in image interpretation. Herring-bone patterns have also been observed. Our first request for a NASA CCT was telexed on 16th November, 1979: we have not yet received a response. A similar request, put to Lannion on 13th July, 1979, was filled when the tape arrived on 6th August, 1979. Unfortunately we have not been able to use the tape because Lannion has not responded sufficiently to subsequent telexes requesting tape reading information.

NASA transparencies, and Lannion QL prints, have been delivered satisfactorily and at a convenient rate.

2-14/P6-11

Recommendations

The laboratory and computer simulations (2-14/P6-5) of oil slicks have yielded interesting initial results and it is our intention to follow these programmes with further experimental work involving the use of a wind tunnel. The indications are that a spill of uniform thickness at sea may be warmer, or cooler, than its surroundings: the Anglesey spill, if correctly identified, proved cooler than the surrounding water at the time the HCMM IR image was secured; and it is clearly important to follow up the diagnostic simulation work while continuing the synopsis of the satellite imagery.

2-14/P6-12

Conclusions

The number of stations at which sea surface temperatures are collected by vessels in the seas around the U.K. is, at any one time centring on a time span of six hours, generally insufficient to sustain the production of meaningful isotherm maps. Even with an integration time of five days, rather than one of six hours, local isotherms derived from sea truth are not necessarily reliable; whereas, on a synoptic scale, their reliability hinges on the relative stability of oceanic thermal regimes. With clear skies, calibrated HCMM thermal IR imagery would greatly improve our capability of producing isothermal charts of sea surfaces on a given date and at a given time.

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